California Harmful Algae Risk Mapping (C-HARM) System:

Connecting stakeholders to ecosystem change and developing next-generation harmful algal bloom models

Clarissa Anderson

Executive Director

Southern California Coastal Ocean Observing System (SCCOOS)

Scripps Institution of Oceanography

University of California, San Diego

California Sea Lion Mortality

Toxigenic *Pseudo-nitzschia*

California Sea Lion Domoic Acid Toxicosis

California Harmful Algae Risk Mapping (C-HARM) System: CROSSING THE "VALLEY OF DEATH" to ARL9

REMOTE SENSING OCEAN COLOR* & SST *VIIRS

Transition Development
CeNCOOS to NCCOS
Final Implementation
NOAA CoastWatch

DINEOF

RECONSTRUCTED OCEAN COLOR & SST

Transition Development
CeNCOOS to NCCOS
Final Implementation
NOAA CoastWatch

HYDRODYNAMIC MODEL FIELDS

Transition Development
RSS ROMS
Final Implementation
WCOFS at CSDL

IOOS
COMT

***IN SITU* OBSERVATIONAL DATA**

Transition Development
CeNCOOS
Final Implementation
SCCOOS & CeNCOOS

CROWDSOURCED DATA

Transition Development
CeNCOOS
Final Implementation
SCCOOS & Marine Mammal Health Map

REGIONAL OPERATIONAL FORECAST PRODUCTS
Transition Development
NOAA NCCOS
Final Implementation
NESDIS/NOAA CoastWatch

DINEOF (FORECAST)

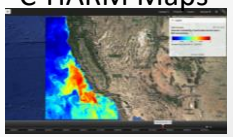
BIOLOGICAL MODEL FIELDS

Transition Development
CeNCOOS*
Final Implementation
NOAA CoastWatch

*S4 HPC @ Univ of WI

INTEGRATED FORECAST & ANALYSIS TOOL

C-HARM Maps



California HAB Bulletin

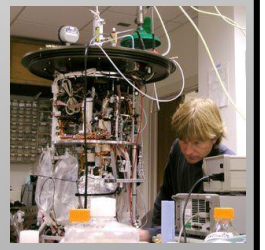
OBIS

HABMAP SCCOOS & CeNCOOS

Near real-time Marine Mammal Stranding Data

Imaging Flow Cytobot Catalina Sea Ranch SF and Monterey Bays

Scripps Plankton Camera, Jules Jaffe



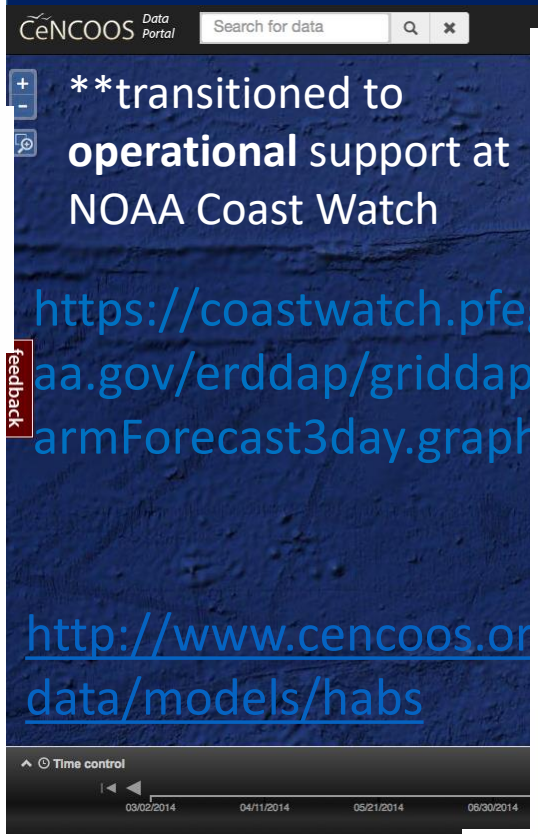
Environmental Sampling Processor (ESP) - Monterey

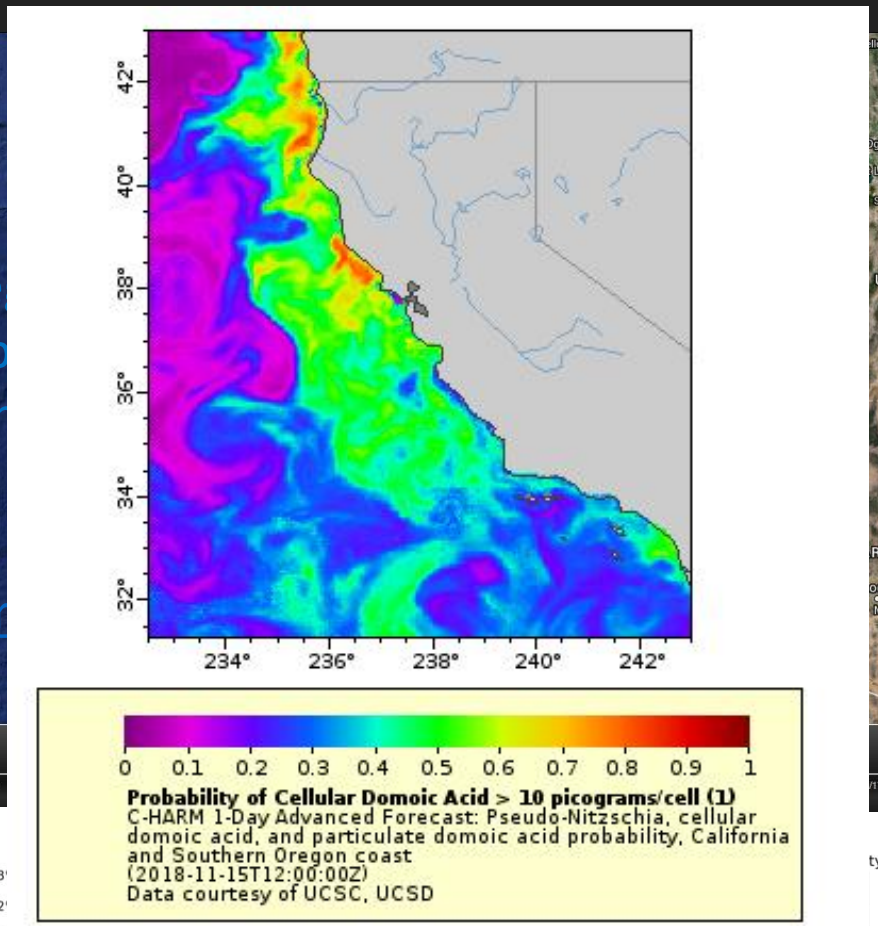
NCCOS = National Centers for Coastal Ocean Science
CSDL = Coast Survey Development Lab
RSS = Remote Sensing Solutions, Inc.
WCOFS = West Coast Ocean Forecast System

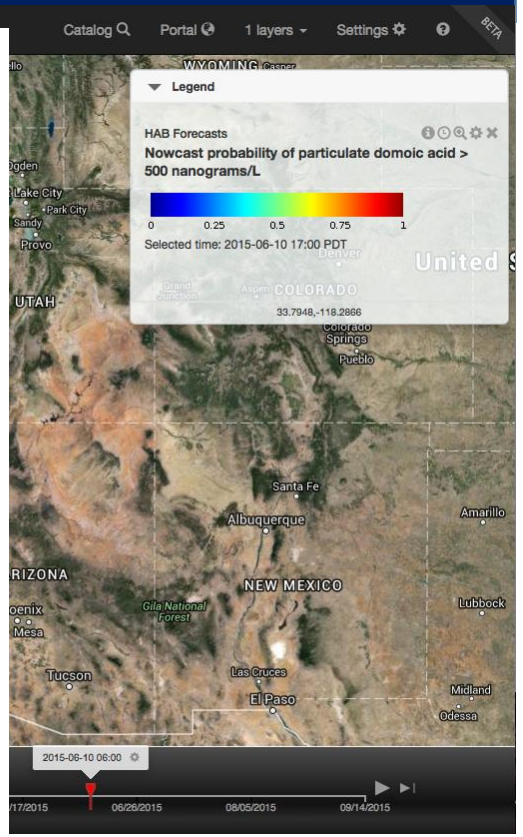
"Operational" Centers
NOAA Coast Watch, West Coast Node
SCCOOS = Southern California Coastal Ocean Observing System
CeNCOOS = Central and Northern California Ocean Observing System

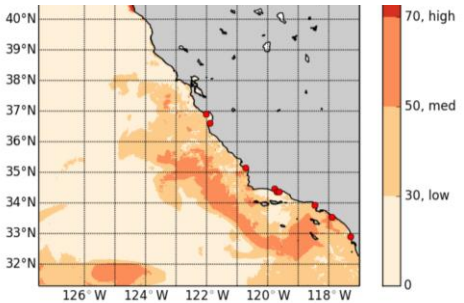
California Harmful Algae Mapping (C-HARM) System

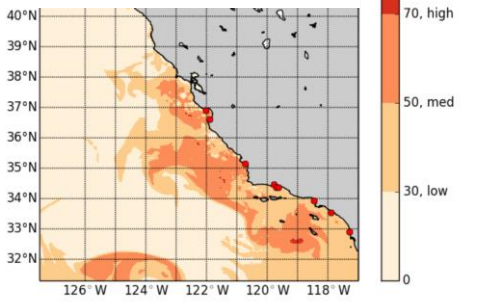
Anderson et al., *Harmful Algae* (2009), *GRL* (2011), *Harmful Algae* (2016)











Extensive collaboration with a partners on creation of a monthly **CA HAB Bulletin** distributed via listserv and SCCOOS & HABMAP

Stakeholder engagement is done via web surveys and continual outreach to super end-users

LAST SLIDE FROM LAST YEAR'S PRESENTATION

FUTURE WORK

Good-bye NASA, hello NOAA

- Create an **empirical model that predicts higher-trophic level toxicity** from coastal C-HARM predictions of domoic acid
  **proposal to California Ocean Protection Council/Sea Grant*

- **Create end-to-end models of HAB risk and bioaccumulation in the food web in an ESM framework**
  *****new funding from NOAA ECOHAB & former seed funding from the Packard Foundation:

Huge thanks to Woody Turner for this opportunity!

WHAT DID THE FUTURE ACTUALLY HOLD?

IOOS COMT Project + Stakeholder Engagement + NOAA ECOHAB

****

- Test utility/performance of new **West Coast Ocean Forecasting System (WCOFS)** with C-HARM, EcoCast, and other ecological forecasting models

  - New funding from IOOS Coastal Ocean Modeling Testbed (COMT)
  - Connect stakeholders to ecosystem change through ecological forecasting

- Create end-to-end models of HAB risk and bioaccumulation in the food web in an Earth System Modeling Framework

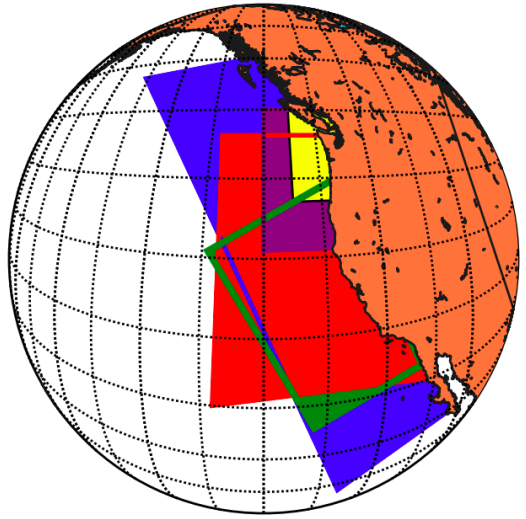
  - New funding from NOAA ECOHAB & former seed funding from the Packard Foundation

IOOS Coastal Ocean Modeling Testbed (COMT) Project

Advancing the West Coast Ocean Forecasting System through Assessment, Model Development, and Ecological Products

Technical PI: Chris Edwards, UCSC
Transition PI: Clarissa Anderson, SCCOOS
Co-PIs:
Alexandre Kurapov, NOAA CO-OPS
Elliott Hazen, SWFSC
Michael Jacox, SWFSC
Jerome Fiechter, UCSC
Raphe Kudela, UCSC
Dale Robinson, CoastWatch-West Coast
Henry Ruhl, CeNCOOS
Jan Newton, NANOOS

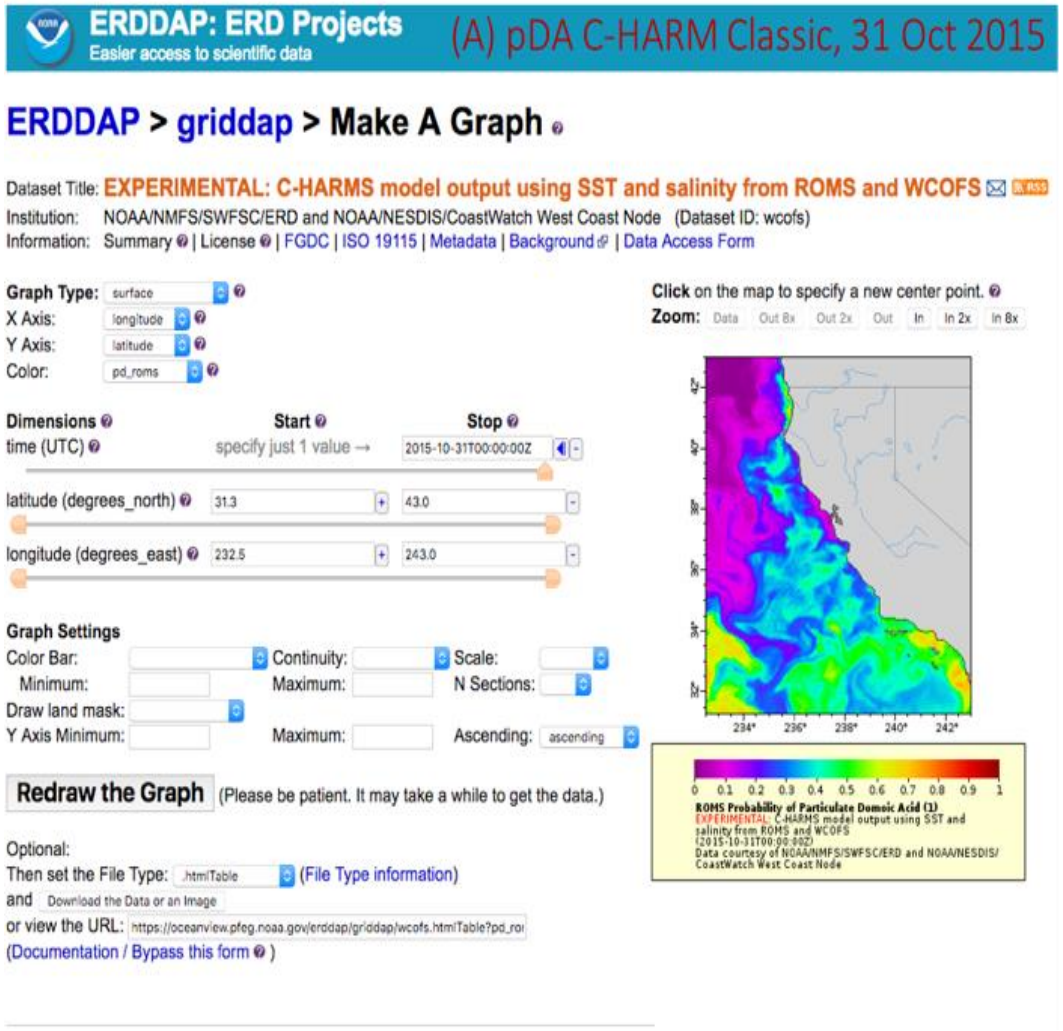
Evaluate C-HARM, EcoCast, & NEMURO with WCOFS

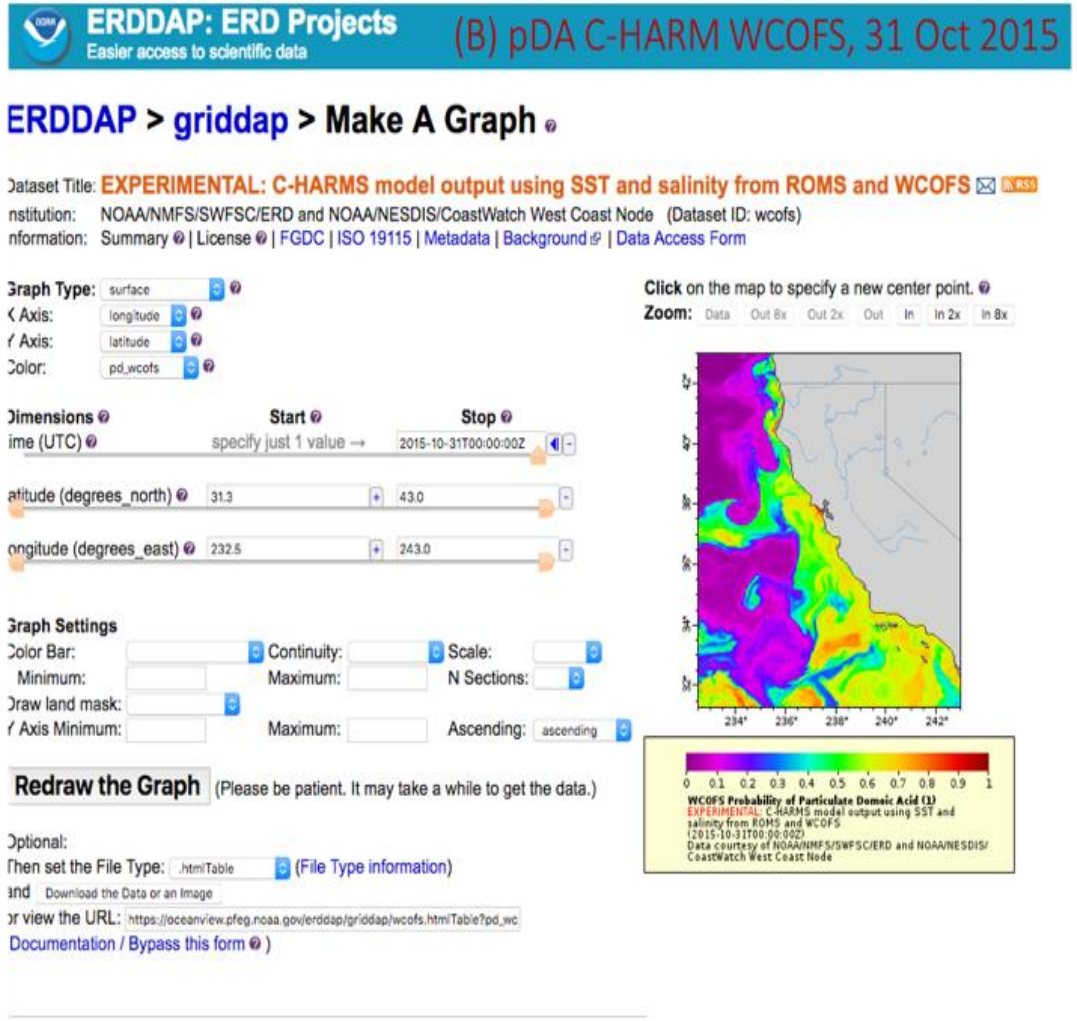


NOAA Integrated Ocean Observing System (IOOS) Coastal Ocean Modeling Testbed: ROMS domains on the west coast: WCOFS, UCSC, CA, OSU, LiveOcean (UW). Despite considerable domain overlap, important differences exist between models in terms of resolution, forcing, biogeochemistry and data assimilation

IOOS Coastal Ocean Modeling Testbed (COMT) Project

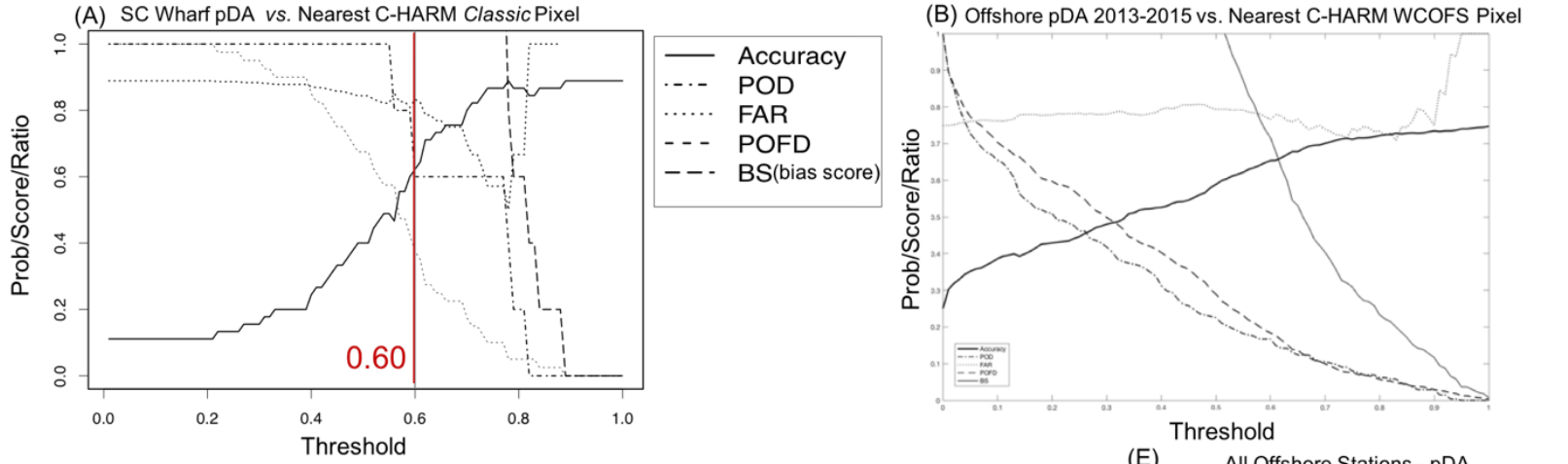
C-HARM *Classic* and C-HARM-WCOFS both served on ERDDAP for evaluation

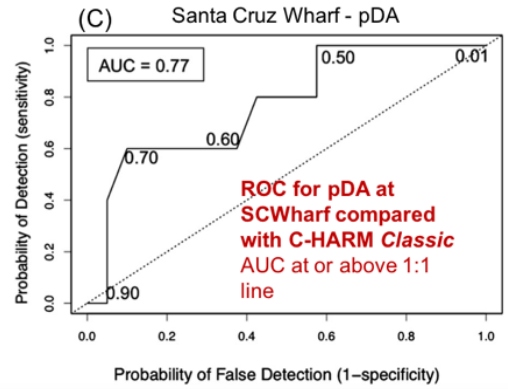


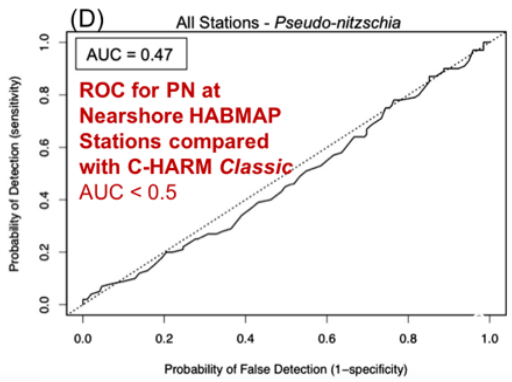


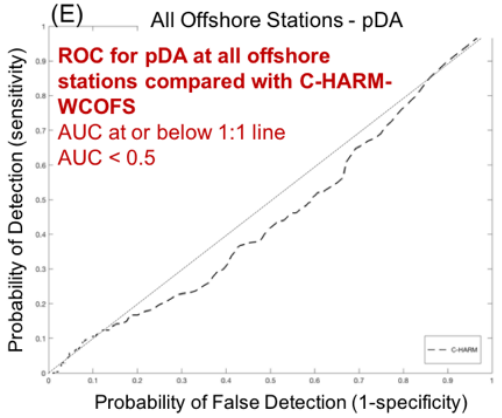
IOOS Coastal Ocean Modeling Testbed (COMT) Project

Preliminary Comparison of nearshore data with C-HARM *Classic* and C-HARM-WCOFS









C-HARM Classic is compared with nearshore HAB monitoring data and with offshore samples collected on 2013 and 2015 cruises and compiled for this study.

Take-home: When C-HARM-*WCOFS* is compared with offshore HAB data, the ROC is similar to that when C-HARM *Classic* is compared with nearshore HAB data from a broad geographic range, and is less ”accurate” than when C-HARM *Classic* was compared with offshore HAB data.

WHAT DID THE FUTURE ACTUALLY HOLD?

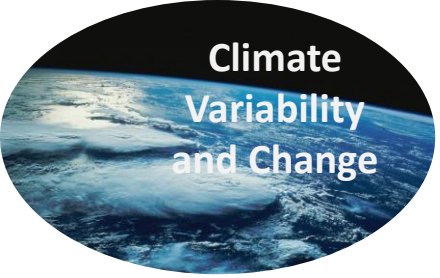
IOOS COMT Project + Stakeholder Engagement + NOAA ECOHAB

- Test utility/performance of new West Coast Ocean Forecasting System (WCOFS) with C-HARM, EcoCast, and other ecological forecasting models

- New funding from IOOS Coastal Ocean Modeling Testbed (COMT)
- **Connect stakeholders to ecosystem change through ecological forecasting**

- Create end-to-end models of HAB risk and bioaccumulation in the food web in an ESM framework

- New funding from NOAA ECOHAB & former seed funding from the Packard Foundation



IOOS
Integrated Ocean
Observing System

CONSISTENT NATIONAL CAPABILITY

assure

Regional Associations

engage

Observations

Data Management

Forecasts/Modeling

User Products

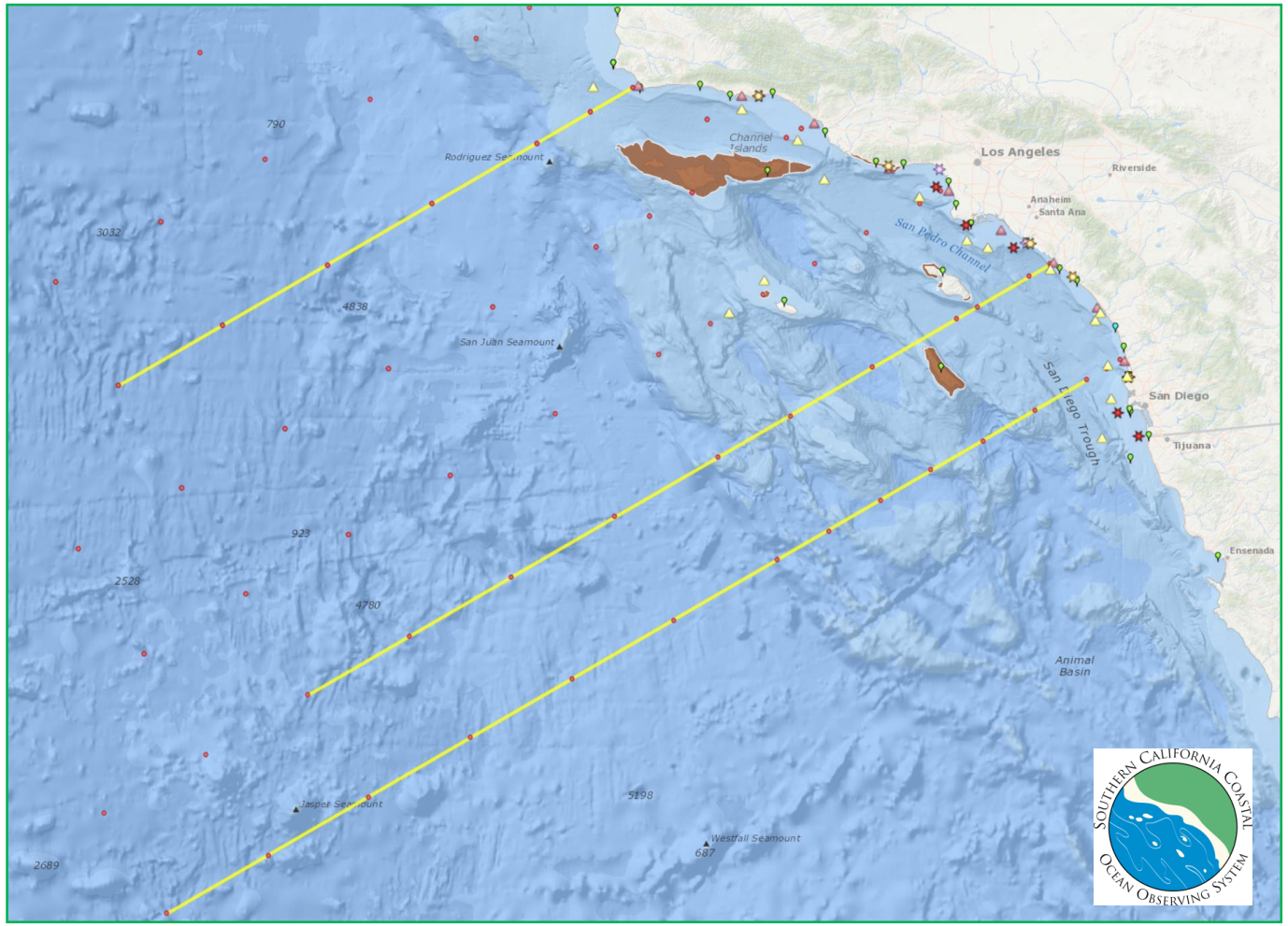
Outreach and Education

Leverage and Link

REGIONAL INFORMATION COORDINATION ENTITY
CERTIFIED
INTEGRATED OCEAN OBSERVING SYSTEM
est. 2015

DIVERSE LOCAL STAKEHOLDERS

Southern California Coastal Ocean Observing System (SCCOOS)



SCCOOS is a science-based decision support system. We provide scientific data and information necessary to address coastal issues.

35 HF Radars

4 Glider Lines

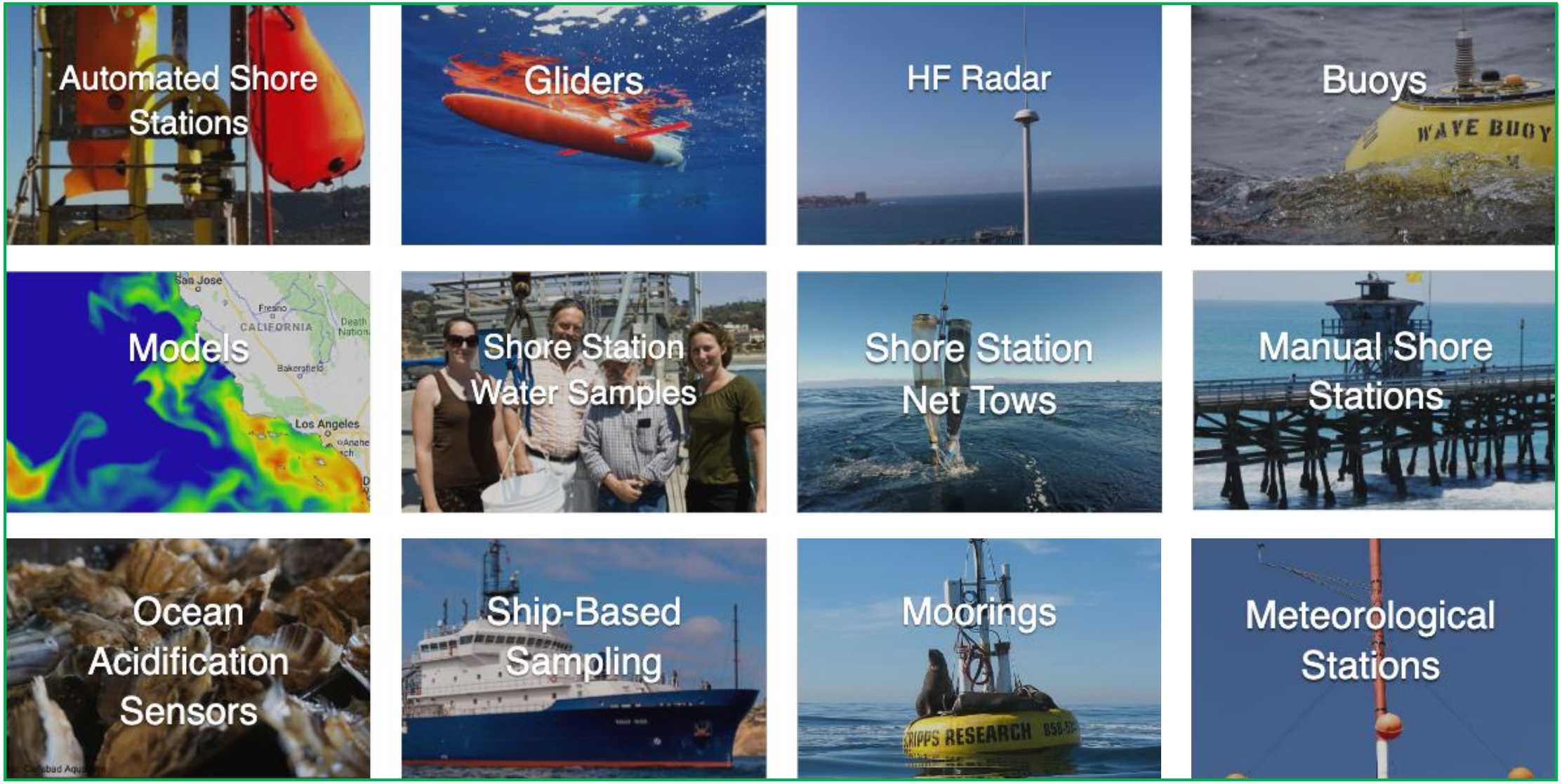
4 Forecast Models

6 Coastal Stations

9 Ship-Based Stations

2 Moorings

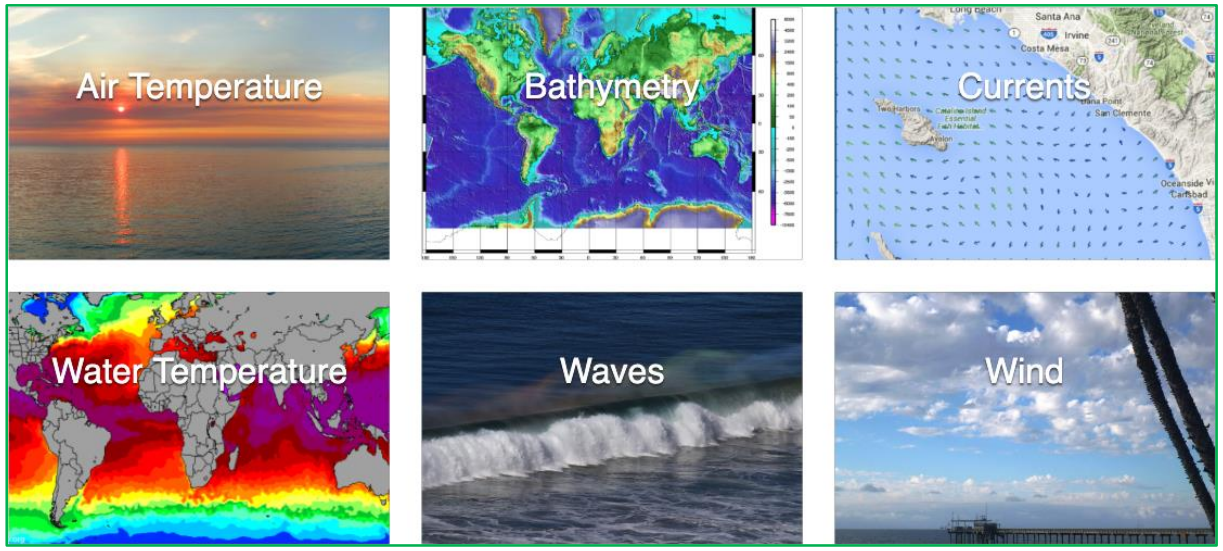
Technologies



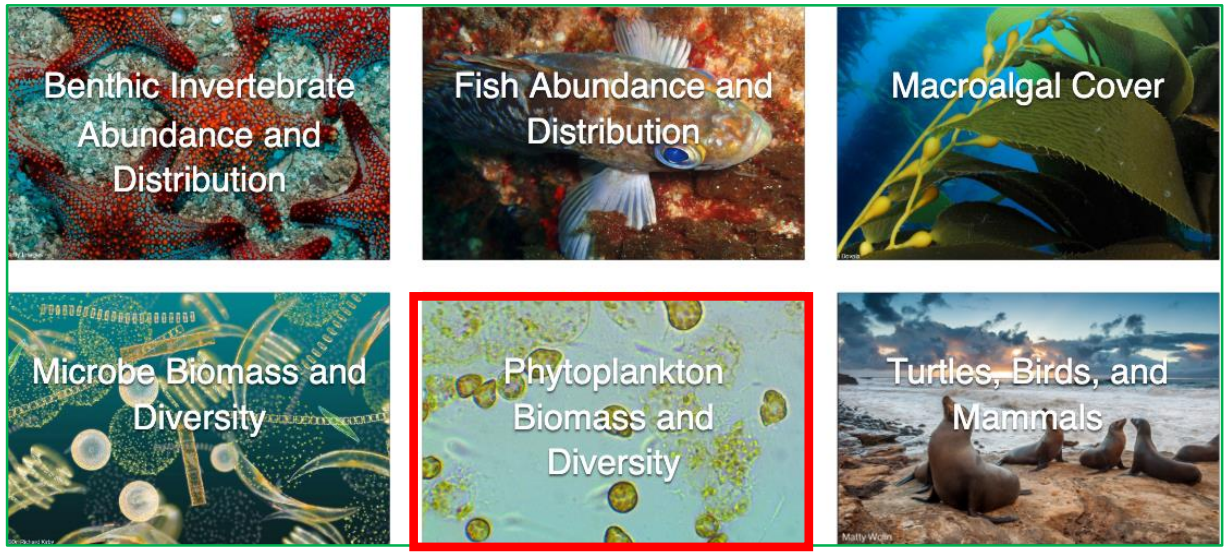
http://sccoos.org/technologies/

Observations – Essential Ocean Variables (GOOS)

Physics



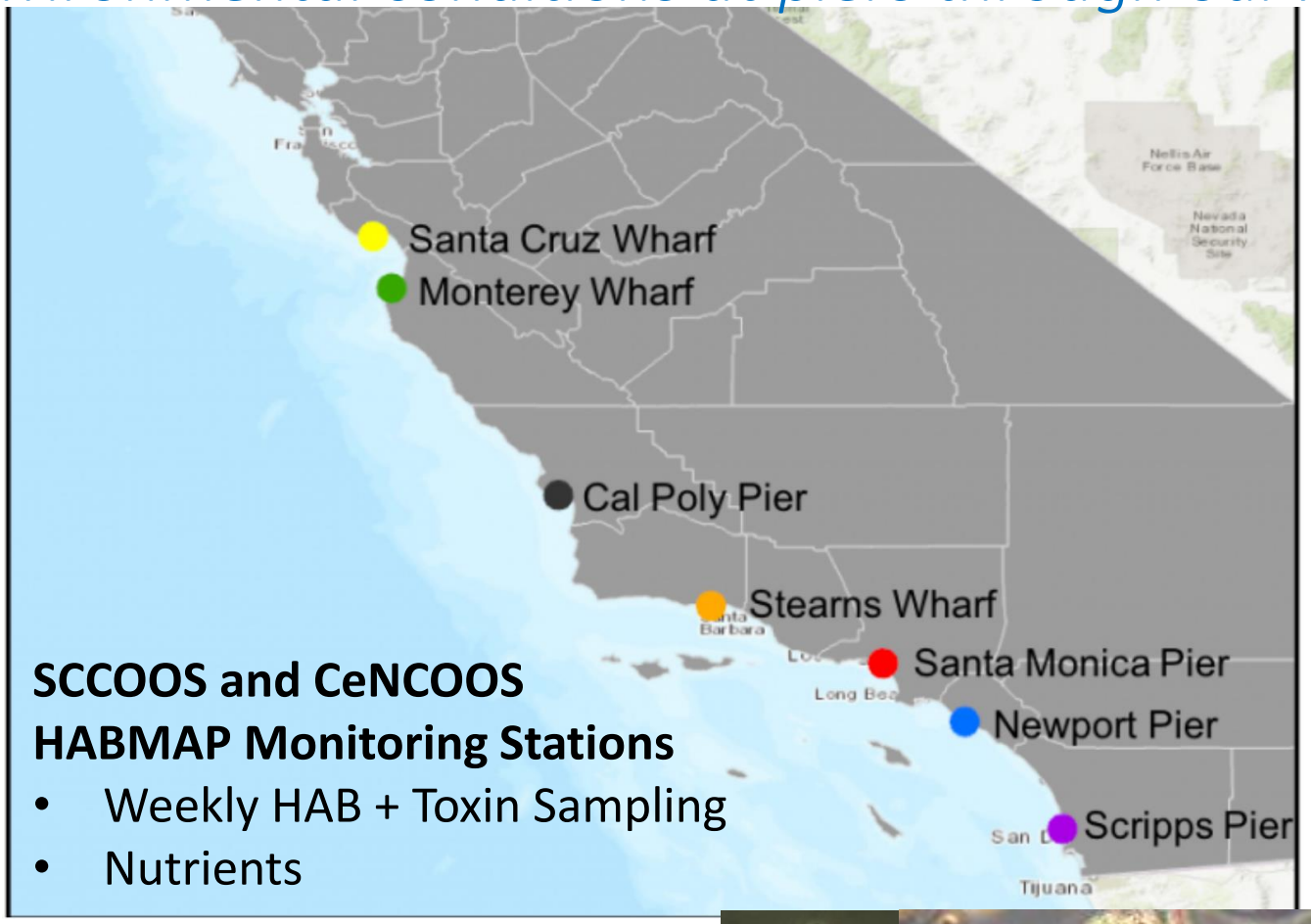
Biology and Ecosystems



Biogeochemistry

http://sccoos.org/observations/

Water Quality: Harmful Algal Blooms – *SCCOOS & CeNCOOS monitor shore stations from San Diego to Santa Cruz for toxins from phytoplankton and measures environmental conditions at piers through our Automated Shore Station Program*



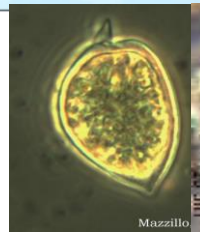
SCCOOS and CeNCOOS
HABMAP Monitoring Stations

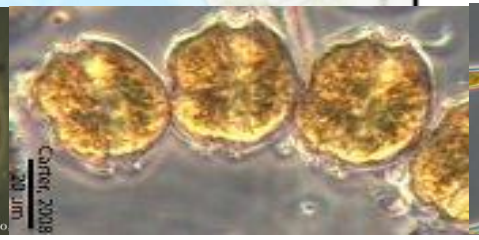
- Weekly HAB + Toxin Sampling
- Nutrients

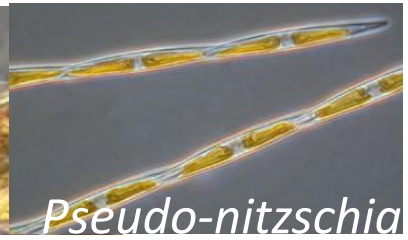
PIs: M. Carter, J. McGowan, C. Anderson, D. Caron R. Shipe, M. Brzezinski, R. Walter/A. Pasulka

IOOS Integrated Ocean Observing System

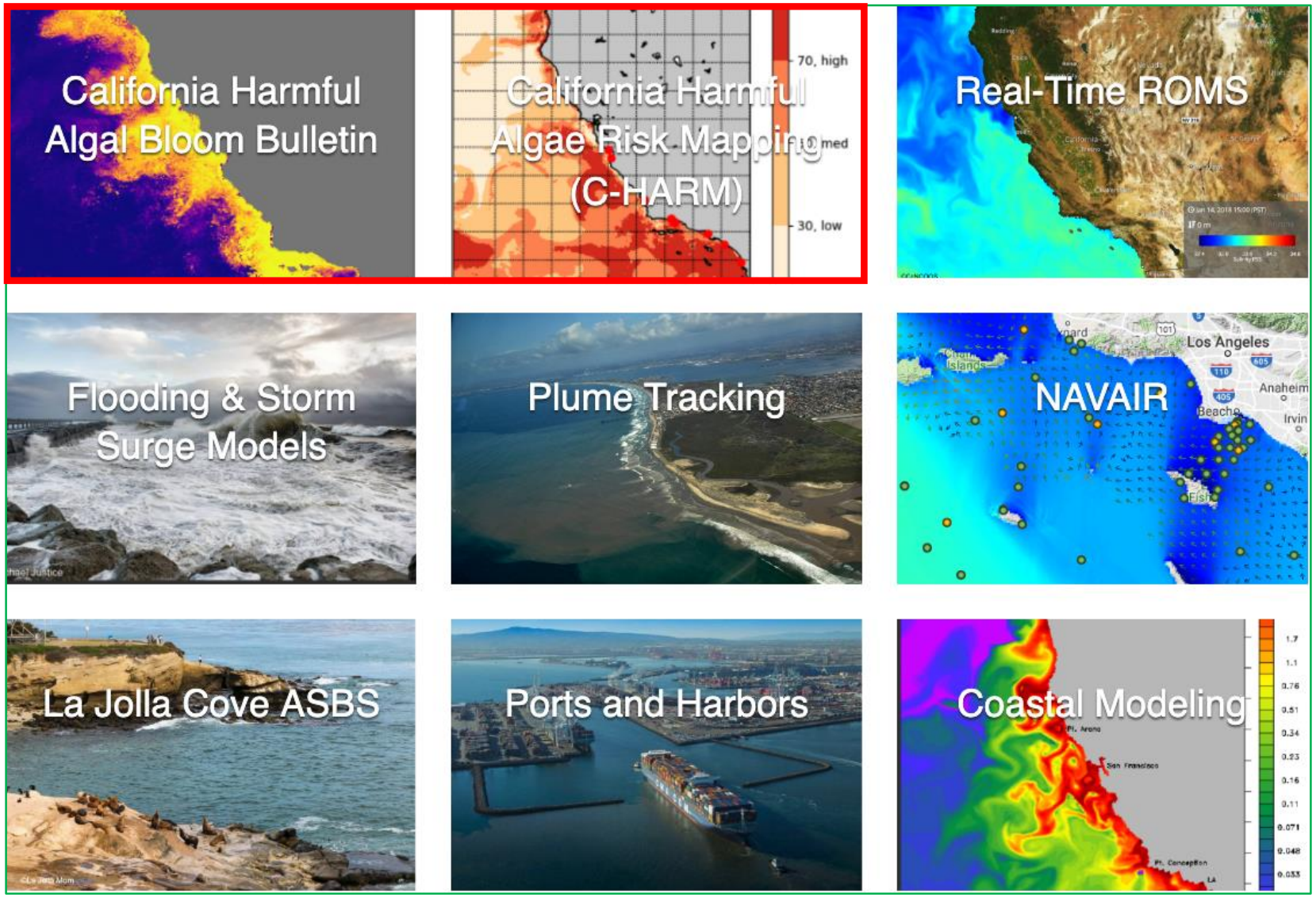
Southern California Coastal Ocean Observing System







Products and Tools



http://sccoos.org/products-and-tools/

California HAB Bulletin

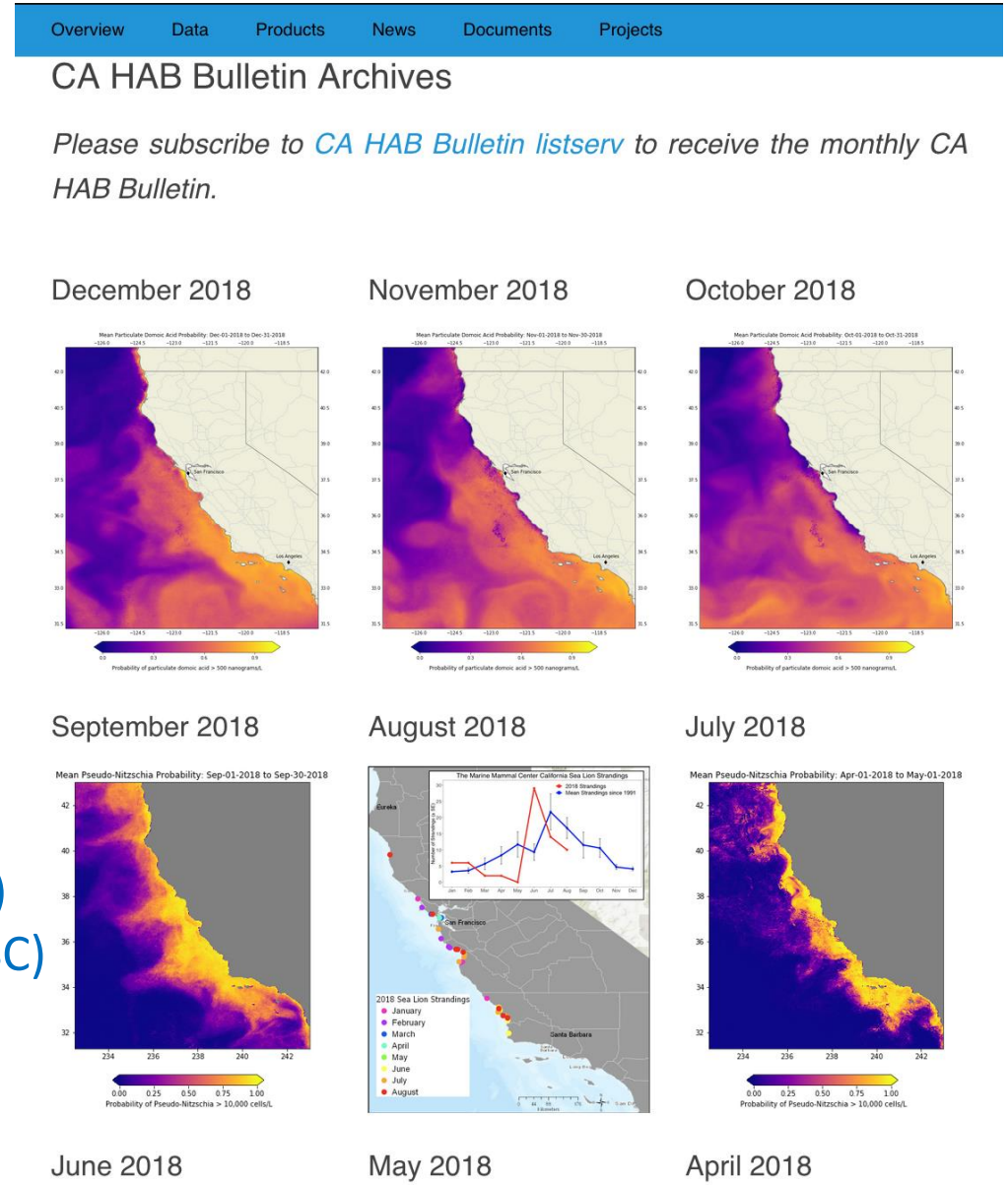
What is the CA HAB Bulletin?

The purpose of this *experimental* product is to give the public and resource managers a quick outlook of recent toxic (marine) algal blooms in coastal California from models and aggregate data sets. **Monthly reports synthesize model output, near real-time observations, animal strandings, and public health alerts** to provide a more complete picture of the regional variability in harmful algal blooms for stakeholders.

Contributors and Stakeholders

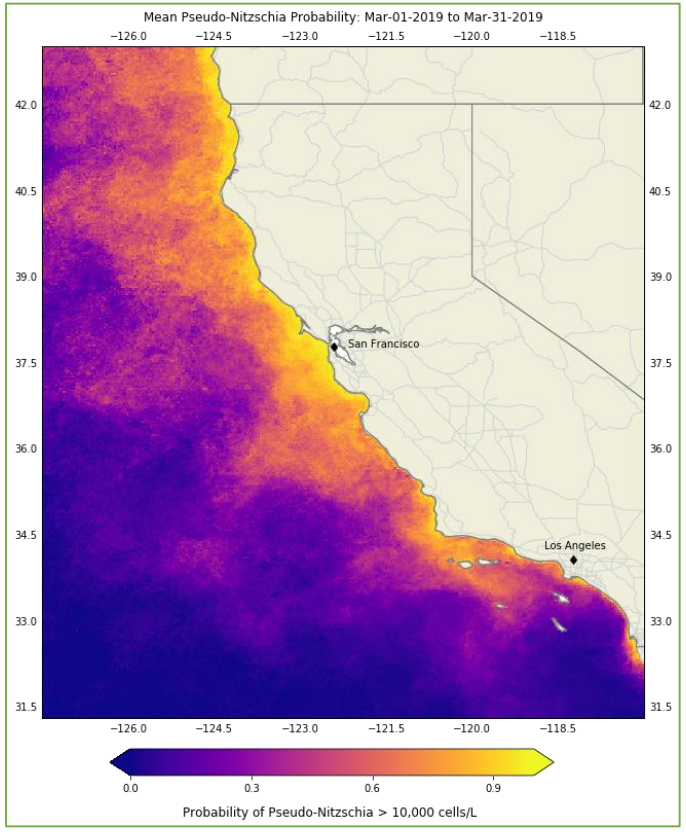
- Aquaculture facilities
- California Department of Public Health (CDPH)
- Office of Environmental Health Hazard Assessment (OEHHA)
- NOAA Fisheries – Southwest Fisheries Science Center (SWFSC)
- Marine mammal rescue groups
- NOAA NCCOS – national HAB end-users
- Academia

sccoos.org/california-hab-bulletin/

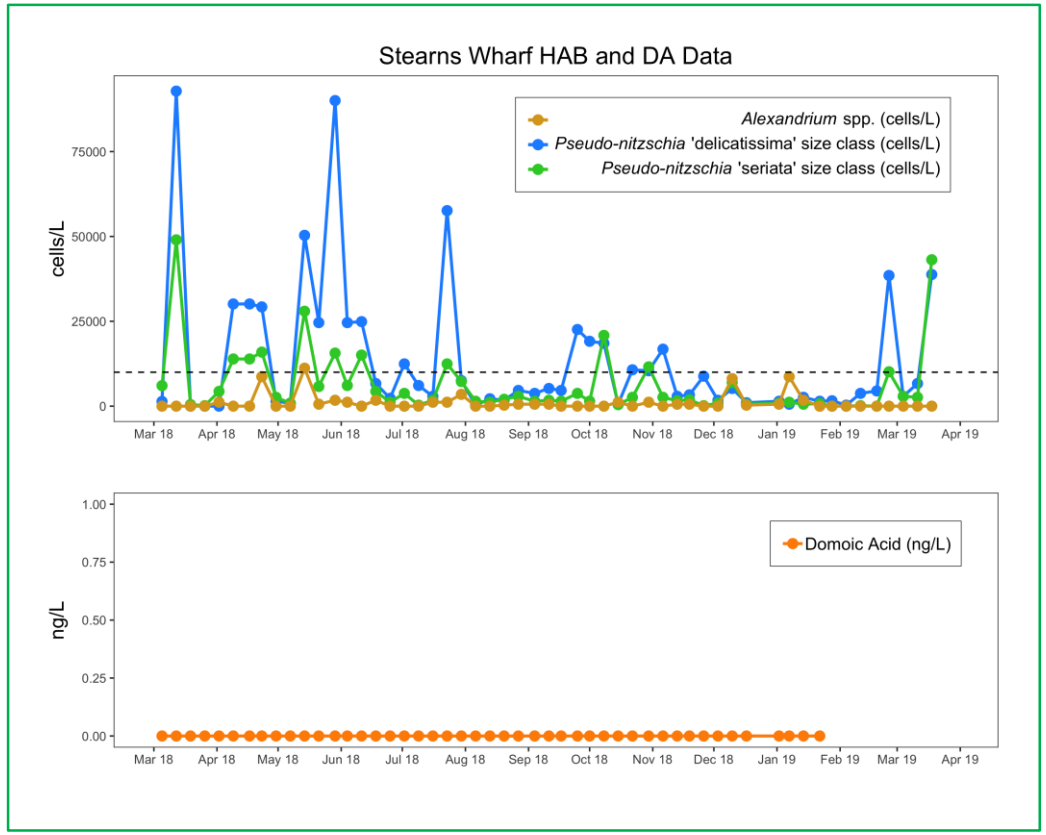


California HAB Bulletin

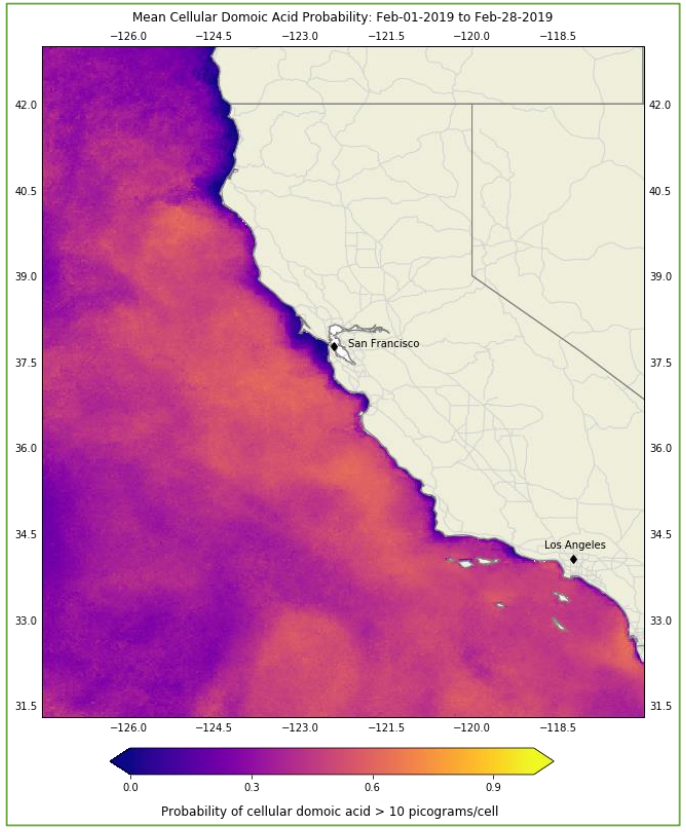
C-HARM
Pseudo-nitzschia, March 2019



HAB Monitoring Alert Program (HABMAP)



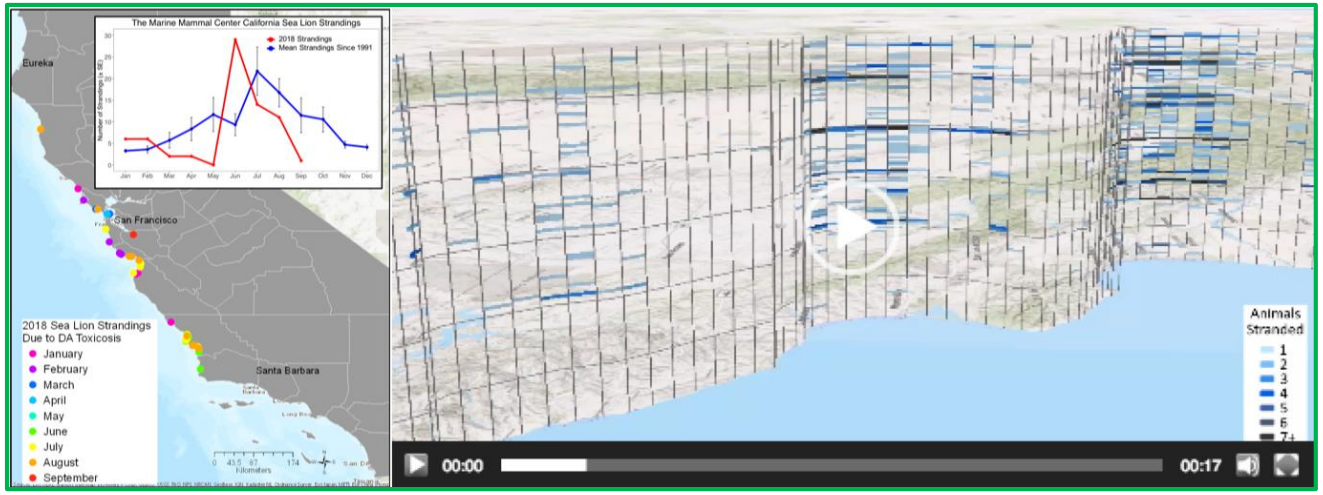
C-HARM
Particulate DA, Feb 2019



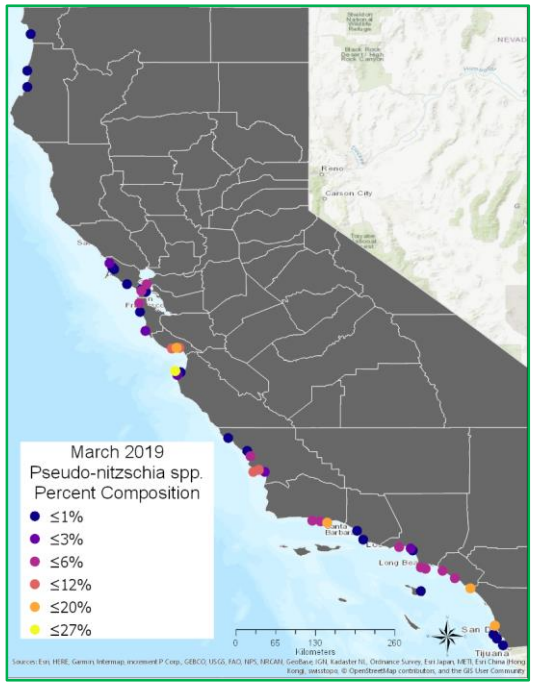
HABMAP monitoring at 7-9 stations for HAB species and domoic acid

California HAB Bulletin

The Marine Mammal Center (TMMC) – Sea lion strandings due to domoic acid toxicosis



CA Department of Public Health (CDPH)



Stranding Rescue Centers

sccoos.org/california-hab-bulletin/

WHAT DID THE FUTURE ACTUALLY HOLD?

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- Connect stakeholders to ecosystem change through ecological forecasting

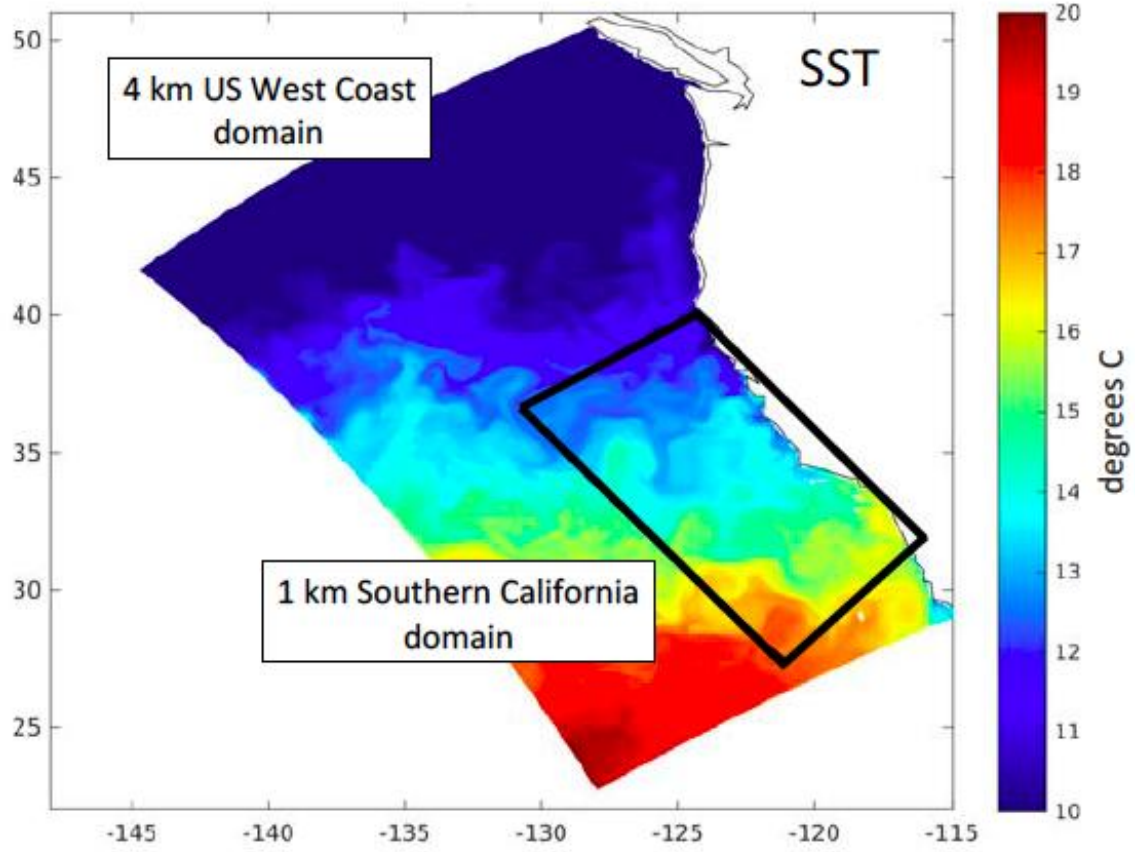
- Create end-to-end models of HAB risk and bioaccumulation in the food web in an ESM framework

- **New funding from NOAA ECOHAB & former seed funding from the Packard Foundation**

High(ish)-Resolution (Nested) Coupled Models

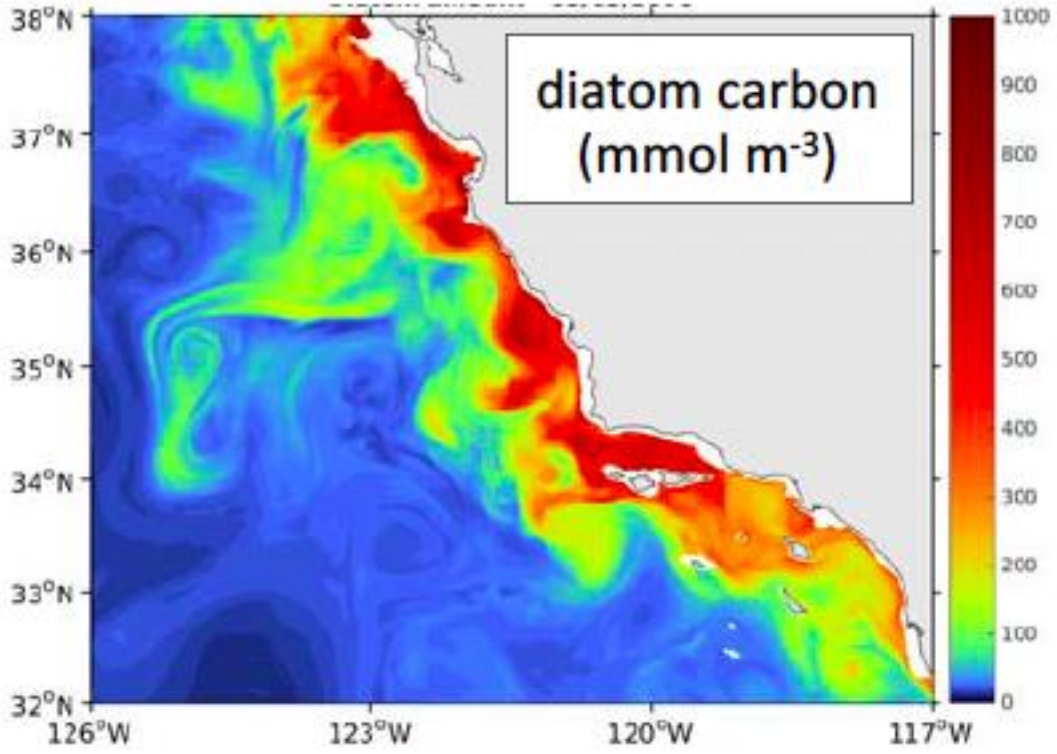
-regional downscaling of the physics + moderate biological complexity in the ecosystem model

REGIONAL OCEAN MODEL SYSTEM (ROMS)



uses nested grids to move across scales
(e.g. Shchepetkin and McWilliams, 2003)
-atmospheric boundary conditions from WRF

ROMS coupled to the Biogeochemical Elemental Cycling (BEC) model

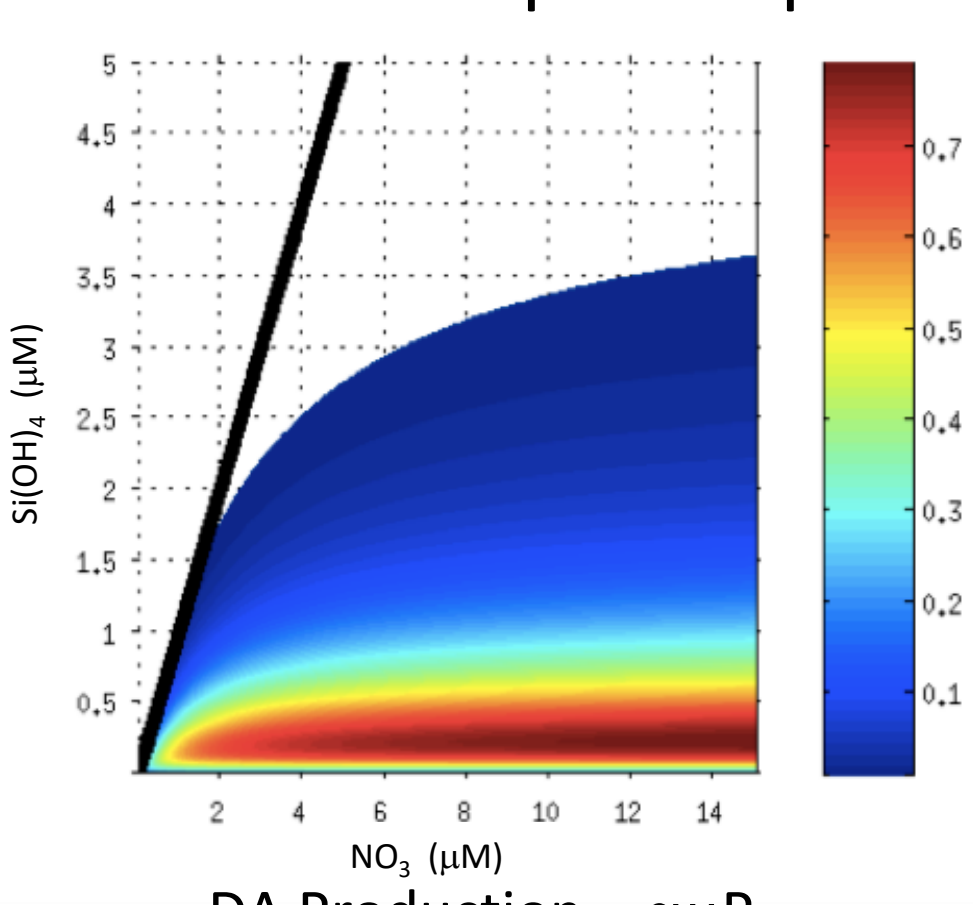


McWilliams-Gruber-Deutsch-Bianchi

2-km configuration (1978-2013)

(does not resolve rivers or point-source discharge)

High(ish)-Resolution (Nested) Coupled Models with explicit representation of HAB species + toxins



DA Production = $\alpha\mu P$

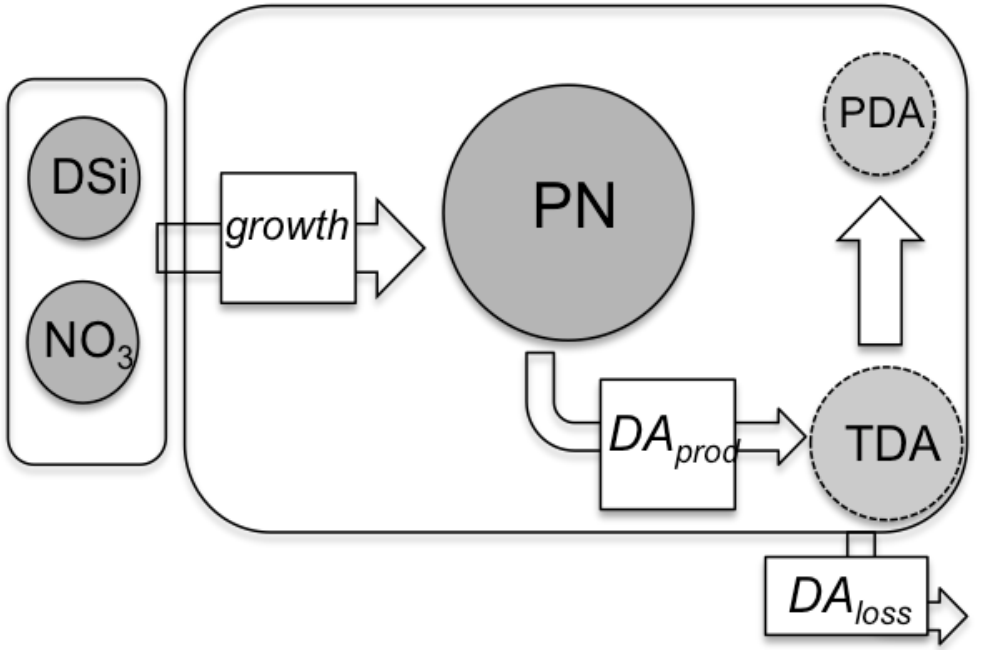
This can be tested with an adjustment to α:

$\alpha = \beta\,[1 - \min((SiLim/NO_3Lim), 1)]^{\gamma}$

Anderson, Edwards, Goebel, & Kudela, unpublished

*New **NOAA ECOHAB** funding *to develop & evaluate 3D-coupled ROMS-BEC model with embedded HAB module* (PIs: Bianchi, McWilliams, Anderson, Kudela, Sutula)

Proposed Model



- Silicic Acid and Nitrate are the fundamental limiting factors driving toxin production in this mechanistic model.

Thanks to NASA ASP for this opportunity

NASA Applied Sciences, Ocean Biology and Biogeochemistry, Energy and Water Cycle

Collaborators:

Raphe Kudela
Mati Kahru
Yi Chao
Fred Bahr
Dale Robinson
Rick Stumpf
Yizhen Li
Eric Bjorkstedt
Brett Stacey

NOAA NCCOS CRP
MERHAB & ECOHAB
NOAA OAP

UC San Diego | SCRIPPS INSTITUTION OF OCEANOGRAPHY